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jc853 U.S. PTO
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PTO/SB/05 (4/98)
Approved for use through 09/30/2000. OMB 0651-0032
Patent and Trademark Office: U.S. DEPARTMENT OF COMMERCE

UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 C.F.R. § 1.53(b))

Attorney Docket No.	ATI-000118BN
First Inventor or Application Identifier	Selvaggi et al.
Title	VERTEX DATA PROCESSING WITH MULTIPLE THREADS OF EXECUTION
Express Mail Label No.	EL566348792

jc869 U.S. PTO
09/632293
08/04/00

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: **Commissioner for Patents, Box Patent Application, Washington, DC 20231**

1. [X] * Fee Transmittal Form *(e.g., PTO/SB/17)* *(Submit an original and a duplicate for fee processing)*
2. [X] Specification [*Total Pages* 12] *(preferred arrangement set forth below)*
   - Descriptive title of the Invention
   - Cross References to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to Microfiche Appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings (*if filed*)
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
3. [X] Drawing(s) *(35 U.S.C. 113)* [*Total Sheets* 8]
4. Oath or Declaration [*Total Pages* 3]
   a. [X] Newly executed (original or copy)
   b. [ ] Copy from a prior application (37 C.F.R. § 1.63(d)) *(for continuation/divisional with Box 16 completed)*
      i. [ ] DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 C.F.R. §§ 1.63(d)(2) and 1.33(b).

NOTE FOR ITEMS 1 & 13: IN ORDER TO BE ENTITLED TO PAY SMALL ENTITY FEES, A SMALL ENTITY STATEMENT IS REQUIRED (37 C.F.R. § 1.27), EXCEPT IF ONE FILED IN A PRIOR APPLICATION IS RELIED UPON (37 C.F.R. § 1.28).

5. [ ] Microfiche Computer Program *(Appendix)*
6. Nucleotide and/or Amino Acid Sequence Submission (*if applicable, all necessary*)
   a. [ ] Computer Readable Copy
   b. [ ] Paper Copy (identical to computer copy)
   c. [ ] Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

7. [X] Assignment Papers (cover sheet & document(s))
8. [ ] 37 C.F.R.§3.73(b) Statement *(when there is an assignee)* [ ] Power of Attorney
9. [ ] English Translation Document *(if applicable)*
10. [ ] Information Disclosure Statement (IDS)/PTO-1449 [ ] Copies of IDS Citations
11. [ ] Preliminary Amendment
12. [X] Return Receipt Postcard (MPEP 503) *(Should be specifically itemized)*
13. [ ] * Small Entity Statement(s) *(PTO/SB/09-12)* [ ] Statement filed in prior application, Status still proper and desired
14. [ ] Certified Copy of Priority Document(s) *(if foreign priority is claimed)*
15. [X] Other: Certificate of Mailing by Express Mail and a check in the amount of $730.

16. If a CONTINUING APPLICATION, *check appropriate box, and supply the requisite information below and in a preliminary amendment:*

[ ] Continuation [ ] Divisional [ ] Continuation-in-part (CIP) of prior application No: ______

Prior application information: *Examiner* ______ *Group / Art Unit:* ______

For CONTINUATION or DIVISIONAL APPS only: The entire disclosure of the prior application, from which an oath or declaration is supplied under Box 4b, is considered a part of the disclosure of the accompanying continuation or divisional application and is hereby incorporated by reference. The incorporation can only be relied upon when a portion has been inadvertently omitted from the submitted application parts.

17. CORRESPONDENCE ADDRESS

[X] *Customer Number or Bar Code Label* 25310 *(Insert Customer No. or Attach bar code label here)* *or* [ ] *Correspondence address below*

Name	VOLPE AND KOENIG, P.C.				
	DEPT ATI				
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City		*State*		*Zip Code*	
Country		*Telephone*		*Fax*	

Name (Print/Type)	Gerald B. Hall, Jr., Esquire	*Registration No. (Attorney/Agent)*	37,633
Signature		*Date*	8/4/00

Express Mail Label No. EL566348792

Volpe and Koenig, P.C. Revision of PTO/SB/17 (12/99)
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Patent fees are subject to annual revision.
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TOTAL AMOUNT OF PAYMENT ($) 730.00

Complete if Known	
Application Number	Not Yet Known
Filing Date	Not Yet Known
First Named Inventor	Selvaggi et al.
Examiner Name	Not Yet Known
Group / Art Unit	Not Yet Known
Attorney Docket No.	ATI-000118BN

METHOD OF PAYMENT (check one)

1. ☐ The Commissioner is hereby authorized to charge the fees indicated hereon:

Deposit Account Number: 22-0493

Deposit Account Name: Volpe and Koenig, P.C.

☒ Charge Any Deficiency or Credit Any Overpayment in the Total Fees Associated with this Communication

Our Order No. 1742

2. ☒ **Payment Enclosed:** ☒ Check ☐ Money Order ☐ Other

FEE CALCULATION

1. BASIC FILING FEE

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
101	690	201	345	Utility filing fee	$690
106	310	206	155	Design filing fee	
107	480	207	240	Plant filing fee	
108	690	208	345	Reissue filing fee	
114	150	214	75	Provisional filing fee	

SUBTOTAL (1) ($) 690.00

2. EXTRA CLAIM FEES

			Extra Claims		Fee from below		Fee Paid
Total Claims	18	- 20** =	0	X	18	=	0
Independent Claims	3	- 3 ** =	0	X	78	=	0
Multiple Dependent					0	=	0

**or number previously paid, if greater; For Reissues, see below

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description
103	18	203	9	Claims in excess of 20
102	78	202	39	Independent claims in excess of 3
104	260	204	130	Multiple dependent claim, if not paid
109	78	209	39	** Reissue independent claims over original patent
110	18	210	9	** Reissue claims in excess of 20 and over original patent

SUBTOTAL (2) ($) 0.00

FEE CALCULATION (continued)

3. ADDITIONAL FEES

Large Entity Fee Code	Large Entity Fee ($)	Small Entity Fee Code	Small Entity Fee ($)	Fee Description	Fee Paid
105	130	205	65	Surcharge - late filing fee or oath	
127	50	227	25	Surcharge - late provisional filing fee or cover sheet.	
139	130	139	130	Non-English specification	
147	2,520	147	2,520	For filing a request for reexamination	
112	920*	112	920*	Requesting publication of SIR prior to Examiner action	
113	1,840*	113	1,840*	Requesting publication of SIR after Examiner action	
115	110	215	55	Extension for reply within first month	
116	380	216	190	Extension for reply within second month	
117	870	217	435	Extension for reply within third month	
118	1,360	218	680	Extension for reply within fourth month	
128	1,850	228	925	Extension for reply within fifth month	
119	300	219	150	Notice of Appeal	
120	300	220	150	Filing a brief in support of an appeal	
121	260	221	130	Request for oral hearing	
138	1,510	138	1,510	Petition to institute a public use proceeding	
140	110	240	55	Petition to revive - unavoidable	
141	1,210	241	605	Petition to revive - unintentional	
142	1,210	242	605	Utility issue fee (or reissue)	
143	430	243	215	Design issue fee	
144	580	244	290	Plant issue fee	
122	130	122	130	Petitions to the Commissioner	
123	50	123	50	Petitions related to provisional applications	
126	240	126	240	Submission of Information Disclosure Stmt	
581	40	581	40	Recording each patent assignment per property (times number of properties)	$40.00
146	690	246	345	Filing a submission after final rejection (37 CFR § 1.129(a))	
149	690	249	345	For each additional invention to be examined (37 CFR § 1.129(b))	

Other fee (specify) ____________

Other fee (specify) ____________

* Reduced by Basic Filing Fee Paid

SUBTOTAL (3) ($) 40.00

SUBMITTED BY				Complete *(if applicable)*	
Name *(Print/Type)*	Gerald B. Halt, Jr., Esquire	Registration No. *(Attorney/Agent)*	37,633	Telephone	215-568-6400
Signature				Date	8/4/00

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Express Mail Label No. EL566348792
PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In the **PATENT APPLICATION** of:

Selvaggi et al.

Application No.: Not Yet Known

Filed: Not Yet Known

For: VERTEX DATA PROCESSING WITH MULTIPLE THREADS OF EXECUTION

Group: Not Yet Known

Examiner: Not Yet Known

Our File: ATI-000118BN

Date: August 4, 2000

CERTIFICATE OF MAILING BY EXPRESS MAIL ACCOMPANYING PATENT APPLICATION

Box PATENT APPLICATION
Commissioner for Patents
Washington, D.C. 20231

Sir:

I hereby certify that the accompanying correspondence is being deposited with the "Express Mail Post Office to Addressee" service of the United States Postal Service in an envelope addressed to Box PATENT APPLICATION, Commissioner for Patents, Washington, D.C. 20231 on August 4, 2000. The number of the "Express Mail" mailing label EL566348792 has been placed on the accompanying correspondence prior to mailing. It is therefore respectfully requested that this correspondence be considered as having been filed in the Office on the date shown above in accordance with the provisions of 37 C.F.R. § 1.10.

Respectfully submitted,

8/4/00
Date

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ATI-000118BN

Express Mail Label No. EL566348792

VERTEX DATA PROCESSING WITH MULTIPLE THREADS OF EXECUTION

BACKGROUND

The addressable and displayable basic element used to build up a computer image is a pixel. Each pixel has several essential parameters stored as the pixel's vertex data. Typical parameters are position data, such as an X coordinate, a Y coordinate and a Z coordinate, that indicate the pixel's reference position in three dimensions (3D); color information, such as diffuse color parameters (R_D, G_D, B_D, A) and specular color parameters (R_S, G_S, B_S, F) which form the pixel's diffuse color and specular color; texture information, such as the pixel's texture pattern and the depth of the pattern from the viewer; or any other suitable information needed by the specific individual application. Based on the graphic standards used by an application, parameters may be stored in different orders or formats within the vertex data. For example, coordinate parameters may be stored as 32-bit floating-point format or fixed-point format. The color information parameters may be stored as a simple group of 4 bytes or as a complicated group of 16 bytes. The graphic device displays the pixel based on its vertex data parameters.

Typical image display systems by using hardware and software have automated several primitive draw functions. For example as shown in Figure 1a, to draw a line, the application needs to provide only the beginning pixel point A 10 (X_1, Y_1, Z_1) and the ending pixel point B 12 (X_2, Y_2, Z_2) to the graphic device 9. The graphic device 9 determines which pixels are on the line between pixel A 10 and pixel B 12. Subsequently, the graphic device 9 sets up these pixels' color information using the A and B pixels' color parameters. If the

application wants to move the line to a new location, the new positions of A 10 will be A′ 14 (X_1+a, Y+b, Z_1) and B 12 will be B′ 16(X_2+a, Y_2+b, Z_2). If a scaling factor c is involved, the new A′ 14 pixel will be (x_1*c+a, y_2*c+b, z_2) and B′ 16 will be (X_2*c+a, Y_2*c+b, Z_2).

The same principle applies to drawing a triangle, another primitive function. An application provides vertex data that has parameters of the three triangle end points. The graphic device 9 will set up the vertex data of all relevant pixels to draw the triangle. All two dimensional (2D) or 3D graphic objects are made up of a number of polygons which can be broken into primitive functions, such as lines, triangles etc. To redraw 2D or 3D graphic objects requires redrawing the relevant primitives. The redrawing requires setting up all corresponding pixels' vertex data and redrawing them. All graphic operations, simple or complicated, are performed by manipulating the contents of pixel vertex data by multiplication, addition or logical operations, such as OR and exclusive OR.

Users of personal computers or game systems utilize real-time effects on displayed images. In such systems, a 2D or 3D image is displayed at a rate of 30 or more frames per second. These rates allow the user to perceive continuous motion of objects in a scene. To achieve such a real-time, realistic and interactive image requires a tremendous amount of processing power. These effects require processing over a million graphic primitives per second. Typically, processing a million primitives requires multiplying and adding millions of floating-point and fixed-point values.

Accordingly, it is desirable to improve the efficiency of transforming vertex data.

SUMMARY

Multi-thread video data processing for use in a computer video display system. The parameters of vertex data are grouped into a plurality of groups. The computation needs of each group are broken down into several arithmetic operations to be performed by corresponding arithmetic units. The units concurrently process the vertex data.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1a illustrates two displayed line images.

Figure 1b is the vertex data of the lines of Figure 1a.

Figure 2 illustrates functional blocks of a setup engine.

Figure 3a is a table of the basic state operations for the position data group.

Figure 3b is a state diagram for the position data group.

Figure 4a is a table of the basic state operations for the color information group.

Figure 4b is the state diagram for the color information group.

Figure 5a is a table of the basic state operations for the texture information group.

Figure 5b is the state diagram flow chart for the texture information group.

Figure 6 illustrates the functional process flow for the transform engine.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Instead of using a traditional sequential processing approach, a multi-thread approach to process the vertex data may be used. As shown in Figures 1a and 1b, computer monitor 9 displays a first line with the beginning pixel point A 10 with parameters X_0, Y_0, Z_0, W_0, S_0, T_0, C_0 and the end pixel point B 12 with parameters X_1, Y_1, Z_1, W_1, S_1, T_1 and C_1 stored as vertex data 20. That line may be modified. It may be moved to a new location, such as to

begin point 14 and end point 16. It may be scaled. It may have its specular color and texture pattern modified. One approach to redrawing the line is to process all parameters of vertex data 20 into new vertex data 40 before the new vertex data 40 is submitted for the line redraw.

The transform process will be explained with reference to modifying a line's pixel vertex data parameters. This transform process may be used for any transformation. As shown in Figure 2, the transform engine 67 is a part of a setup engine 65. Vertex data is transformed by the transform engine 67 and processed by the other data processing engine 68. Subsequently, the transformed and processed data is sent to raster engine 69 prior to output to the monitor 9.

The transform engine 67 initially groups vertex data parameters together for processing. The groups allow for more efficient utilization of each arithmetic unit, such as a floating-point multiplication unit and a floating-point addition unit. One grouping scheme groups: the pixel position vertex data, the pixel color vertex data and the pixel texture vertex data together. To illustrate for a line, the pixels' position data X_0, Y_0, Z_0 and W_0 and X_1, Y_1, Z_1 and W_1 is selected as a first group. The pixels' color data C_0 and C_1 is selected as a second group and the pixels' texture data S_0, T_0 and S_1, T_1 is selected as a third group. By analyzing the computational requirements of each group, the required tasks can be broken down into addition and multiplication operations. The broken down operations are used to construct multiplication and addition state operations. Any computation needs of the group can be fulfilled by using the combination of its basic state operations to achieve the final results. Using sequential states, the addition unit may perform operations such as subtraction, move, floating-point number conversion to fixed number, truncate, round to even, round to odd.

To transform the position data group as shown in Figure 3a, one approach is to use ten basic state operations 80-89. Six 80-85 out of the ten basic 80-89 state operations involve multiplication. Three state operations 86-88 involve addition and one state operation 89 is a wait, no operation (NOP), state operation. There is also an idle state 79. As shown in Figure 3a, position state operation 0 80 involves multiplying the X coordinate by a scale factor. Position state operation 8 88 involves adding the Z coordinate with an offset. For vertex data of the initial line begin pixel A 10 (X_0,Y_0, and Z_0) transforms to A_1 14 ($X_0^{/} = X_0 * c_1 + a_1$, $Y_0^{/} = Y_0 * c_2 + a_2$, $Z_0^{/} = Z_0 * c_3 + a_3$). The transformation will require position state operations (PSO) 0, 6, 1, 7, 2 and 8; 80, 86, 81, 87, 82 and 88 to complete the whole computation. Referring back to Figure 3b, the different paths from one position state operation to other position data state operations are shown.

To transform the color data group, one approach is to use ten independent color state operations (CSO), as shown in Figure 4a. Each CSO involves only addition with one color parameter. CSO 0-3 100-102 are related to diffuse color parameters addition, CSO 4-7 104-107are related to specular color parameters addition, and CSO 8-9 108-109 move the R_s and R_d vertex data. The move operation may be performed using an addition unit. The different paths from one color state operation to other color state operations are shown in Figure 4b. To transform the texture data group, one approach is to use eight texture state operations (TSOs). Six 122-127 of the TSOs are multiplication related and two 120, 121 of the TSOs are moves which can be performed by addition. Figure 5a shows the different paths from one TSO 120-127 to other TSOs 120-127.

By grouping the vertex data into position, color and textural groups, multiple arithmetic units, such as a floating-point multiplication and a floating-point addition unit, may be utilized more efficiently. To illustrate, if position group data is utilizing the floating-multiplication unit to perform a multiplication operation, simultaneously an addition operation of either the color group or texture group can utilize the addition unit. By continuously sending multiplication and addition operations to queues associated with the multiplication and addition units, both the multiplication and addition unit are used with higher efficiency accelerating data processing.

Each of these groups of operations comprise a "program", or "thread of execution" that vies for the use of the shared arithmetic resources. Multiple controllers are typically used, each executing a thread, that can generate a sequence of instruction for the shared arithmetic resources.

It is a common requirement that the vertex data processor be flexible enough, via programmability, to perform a certain subset of all of its possible operations, for any given graphics primitive or vertex. Since the exact operations to be performed by the transform engine are not known until run-time, it is desirable for the processor to respond dynamically to the processing workload to efficiently use the available processing resources. One technique for dynamic processing is to group the operations based on which function unit they use. Subsequently, the operations are concurrently scheduled to each function unit.

To illustrate as shown in Figure 6, the vertex data 140 is broken into three groups; position group 145, color group 150 and texture group 155. The position group 145 requires PSO 0, 6, 1, 7, 2 and 8; 80, 86, 81, 87, 82 and 88 to complete its data transformation. The color group 150 requires CSO 0 and 8; 100 and 108 to complete its transformation. The textural group 150 requires TSO 0 and 2; 120 and 122 to transform the textural parameters.

All multiplication state operations from the position or textural groups 145, 155 will be queued at the multiplication queue 160 and all addition state operations from all three groups 145, 150, 155 will be queued at the addition queue 165. The queued operations of both queues 160, 165 will be independently executed by the multiplier unit 170 and the adder unit 175. The queues are controlled by schedulers, such as an M-scheduler 181 and A-scheduler 182.

In certain circumstances, coordination between threads is needed. For example, intermediate results from the position thread (for example, perspective-related information) may be required by the texture thread. Binary or counting semaphore 180 can be used to synchronize the sequential execution of two different threads and to signal when the result from one thread is available for the next thread to consume. The results of the executed operations are sent to a post-processing engine 185, such as the XEOPIPE, which performs operations, such as rounding or conversion from floating-point to fixed-point format. The buffer 195 holds the transformed vertex data until required by other processes.

* * *

CLAIMS

What is claimed is:

1. A method for processing video image data includes a plurality of different types of data such as position, texture and color data, the method comprising:

providing tasks to be performed on each different type of data of the image data;

dividing the image data into a plurality of groups based on the type of data for each group, determining a set of arithmetic operations required to accomplish the tasks provided for the corresponding type of data;

assigning each arithmetic operation to one of a plurality of commonly used arithmetic units;

performing each arithmetic operation by the assigned arithmetic unit whereby each type of data is transformed in accordance with the corresponding provided tasks; and

combining the transformed data of each group.

2. The method of claim 1 wherein the plurality of data groups comprises a position group for position vertex parameters, a color group for color vertex parameters and a texture group for texture vertex parameters.

3. The method of claims 1 wherein the plurality of said commonly used arithmetic units comprises an addition unit and a multiplication unit.

4. The method of claim 1 wherein the determining a set of arithmetic operations for each task is based on in part by a sequence of arithmetic states.

5. The method of claim 1 further comprising providing a queue for each of the plurality of commonly used arithmetic units and wherein each assigned arithmetic operation is sent to the queue associated with its commonly used arithmetic unit.

6. The method of claim 5 further comprising preventing the arithmetic units from performing the arithmetic operations of a task out of sequence.

7. An apparatus for processing video image data including a plurality of different types of data such as position, texture and color data, the apparatus comprising:

means for providing tasks to be performed on each different type of data of the image data;

means for dividing the image data into a plurality of groups based on the type of data for each group, and for determining a set of arithmetic operations required to accomplish the tasks provided for the corresponding type of data;

means for assigning each arithmetic operation to one of a plurality of commonly used arithmetic units;

means for performing each arithmetic operation by the assigned arithmetic unit whereby each type of data is transformed in accordance with the corresponding provided tasks; and

means for combining the transformed data of each group.

8. The apparatus of claim 7 wherein the plurality of data groups comprises a position group for position vertex parameters, a color group for color vertex parameters and a texture group for texture vertex parameters.

9. The apparatus of claim 7 wherein the plurality of said commonly used arithmetic units comprises an addition unit and a multiplication unit.

10. The apparatus of claim 7 wherein for each data group, the arithmetic operation set comprises a set of arithmetic states and the determined operations for each task are defined by a sequence of the set's arithmetic states.

11. The apparatus of claim 7 further comprising a queue for each of said commonly used arithmetic units and wherein each arithmetic operation is sent to the queue associated with its commonly used arithmetic unit.

12. The apparatus of claim 11 further comprising means for preventing the arithmetic units from performing the arithmetic operations of a task out of sequence.

13. An apparatus for performing video processing, the video processing including performing tasks on vertex parameters, the apparatus comprising:

a scheduler having an input configured to receive tasks and for arranging the vertex parameters to be processed into a plurality of groups based on in part characteristics of the vertex parameters;

the sequencer for each group:

determining the tasks required to process that group's parameters, determining a set of arithmetic operations required to accomplish that group's tasks, each arithmetic operation to be performed by one of a plurality of commonly used arithmetic

units, and sending each of the arithmetic operations of each of that group's tasks to the arithmetic unit associated with that arithmetic operation; and

each of said commonly used arithmetic units, having an input configured to receive the sent arithmetic operations and vertex parameters associated with the sent operations and for performing the sent arithmetic operations on the sent vertex parameters.

14. The apparatus of claim 13 wherein the plurality of groups comprises a position group for position vertex parameters, a color group for color vertex parameters and a texture group for texture vertex parameters.

15. The apparatus of claim 13 wherein the plurality of said commonly used arithmetic units comprises an addition unit and a multiplication unit.

16. The apparatus of claim 13 wherein for each group, the arithmetic operation set comprises a set of arithmetic states and the determined operations for each task are defined by a sequence of the set's arithmetic states.

17. The apparatus of claim 13 further comprising a queue for each of said commonly used arithmetic units and wherein the sent arithmetic operations are sent to the queue associated with its commonly used arithmetic unit.

18. The apparatus of claim 17 wherein the sequencer prevents the arithmetic units from performing the arithmetic operations of a task out of sequence.

ABSTRACT

Multi-thread video data processing for use in a computer video display system. The parameters of vertex data are grouped into a plurality of groups. The computation needs of each group are broken down into several arithmetic operations to be performed by corresponding arithmetic units. The units concurrently process the vertex data.

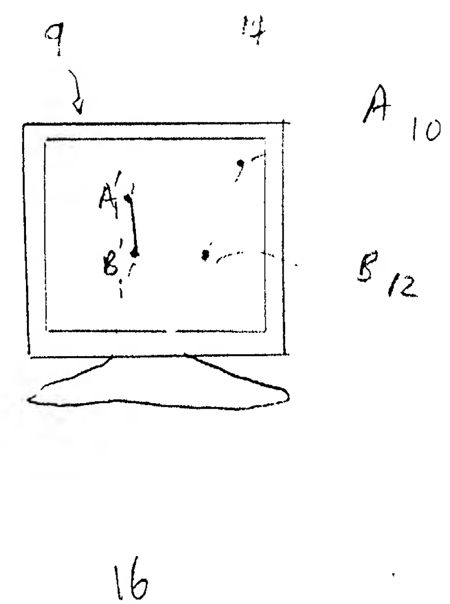

9
14
A 10
B 12
A'
B'
16

FIG. 1A

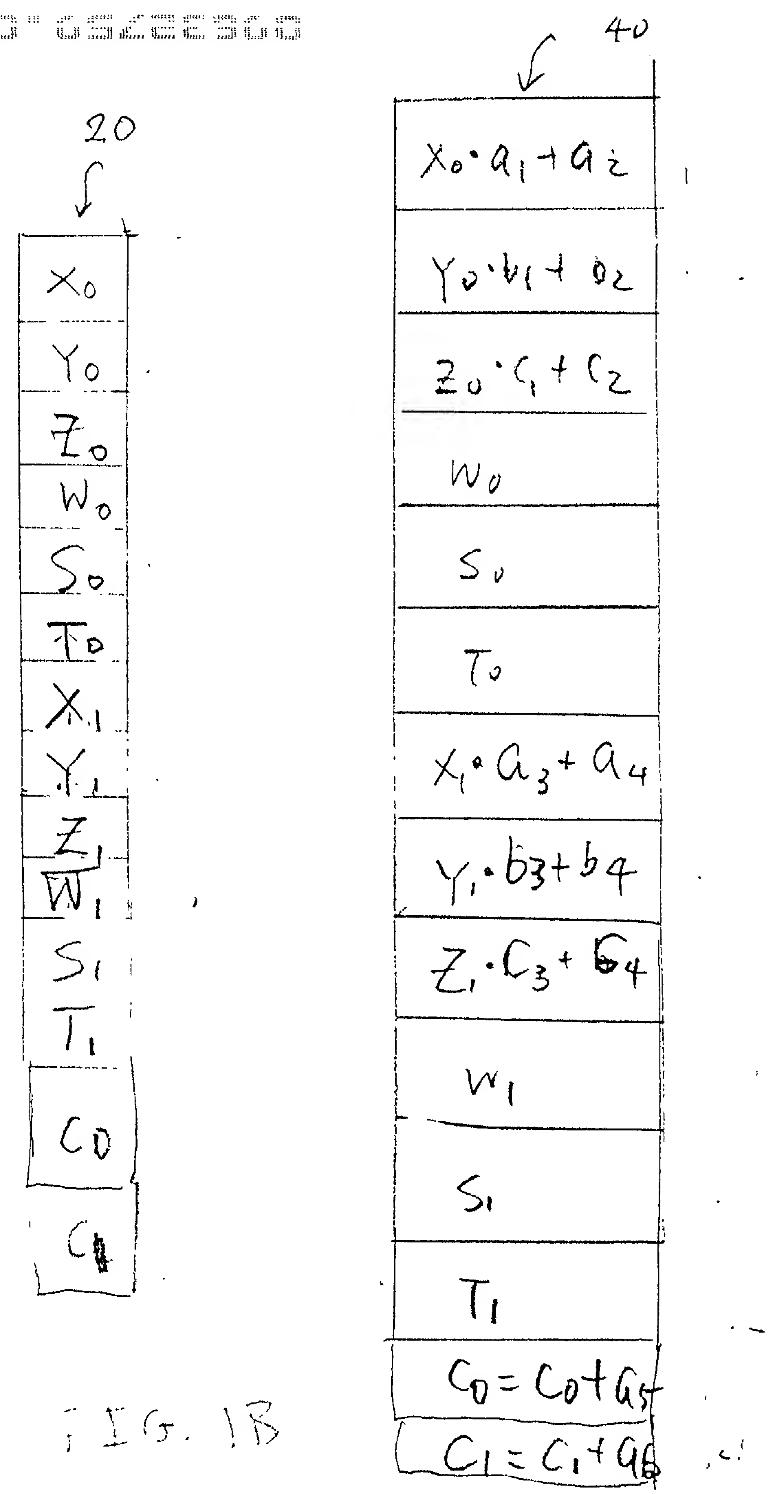

20
X_0
Y_0
Z_0
W_0
S_0
T_0
X_1
Y_1
Z_1
W_1
S_1
T_1
C_0
C_1
40
$X_0 \cdot a_1 + a_2$
$Y_0 \cdot b_1 + b_2$
$Z_0 \cdot c_1 + c_2$
W_0
S_0
T_0
$X_1 \cdot a_3 + a_4$
$Y_1 \cdot b_3 + b_4$
$Z_1 \cdot c_3 + c_4$
W_1
S_1
T_1
$C_0 = C_0 + a_5$
$C_1 = C_1 + a_6$

FIG. 1B

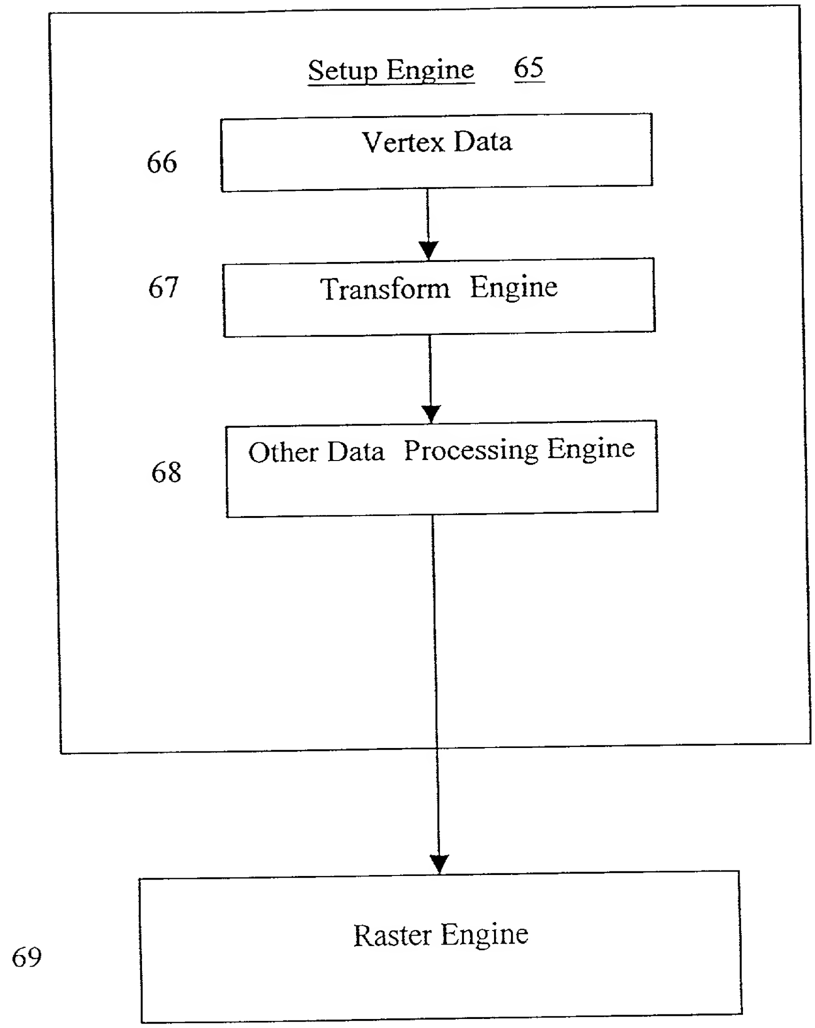

Setup Engine 65
66
Vertex Data
67
Transform Engine
68
Other Data Processing Engine
69
Raster Engine

Figure 2

80 ~	Position State Operation 0	$X = X * C_1$
81 ~	Position State Operation 1	$Y = Y * C_2$
82 ~	Position State Operation 2	$Z = Z * C_3$
83 ~	Position State Operation 3	$X = X * W_0$
84 ~	Position State Operation 4	$Y = Y * W_0$
85 ~	Position State Operation 5	$Z = Z * W_0$
86 ~	Position State Operation 6	$X = X + a_1$
87 ~	Position State Operation 7	$Y = Y + a_2$
88 ~	Position State Operation 8	$Z = Z + a_3$
89 ~	Position State Operation 9	Wait

Figure 3a

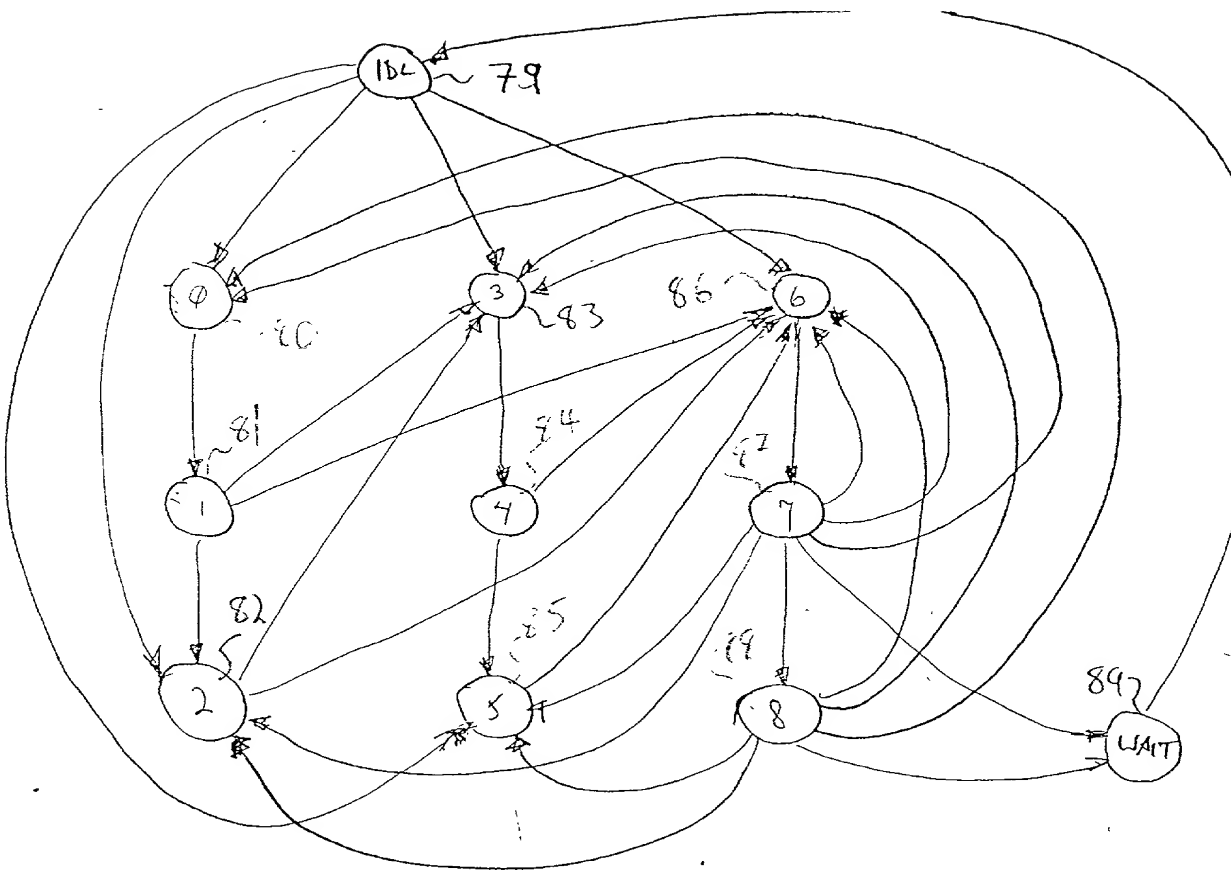


Fig 3b

100 ~	Color State Operation 0	$R_d = R_d + C$
101 ~	Color State Operation 1	$G_d = G_d + C$
102 ~	Color State Operation 2	$B_d = B_d + C$
103 ~	Color State Operation 3	$A = A + C$
104 ~	Color State Operation 4	$R_s = R_s + C$
105 ~	Color State Operation 5	$G_s = G_s + C$
106 ~	Color State Operation 6	$B_s = B_s + C$
107 ~	Color State Operation 7	$F = F + C$
108 ~	Color State Operation 8	$R_d = R_d$
109 ~	Color State Operation 9	$R_s = R_s$
110 ~	NOP	

Figure 4a

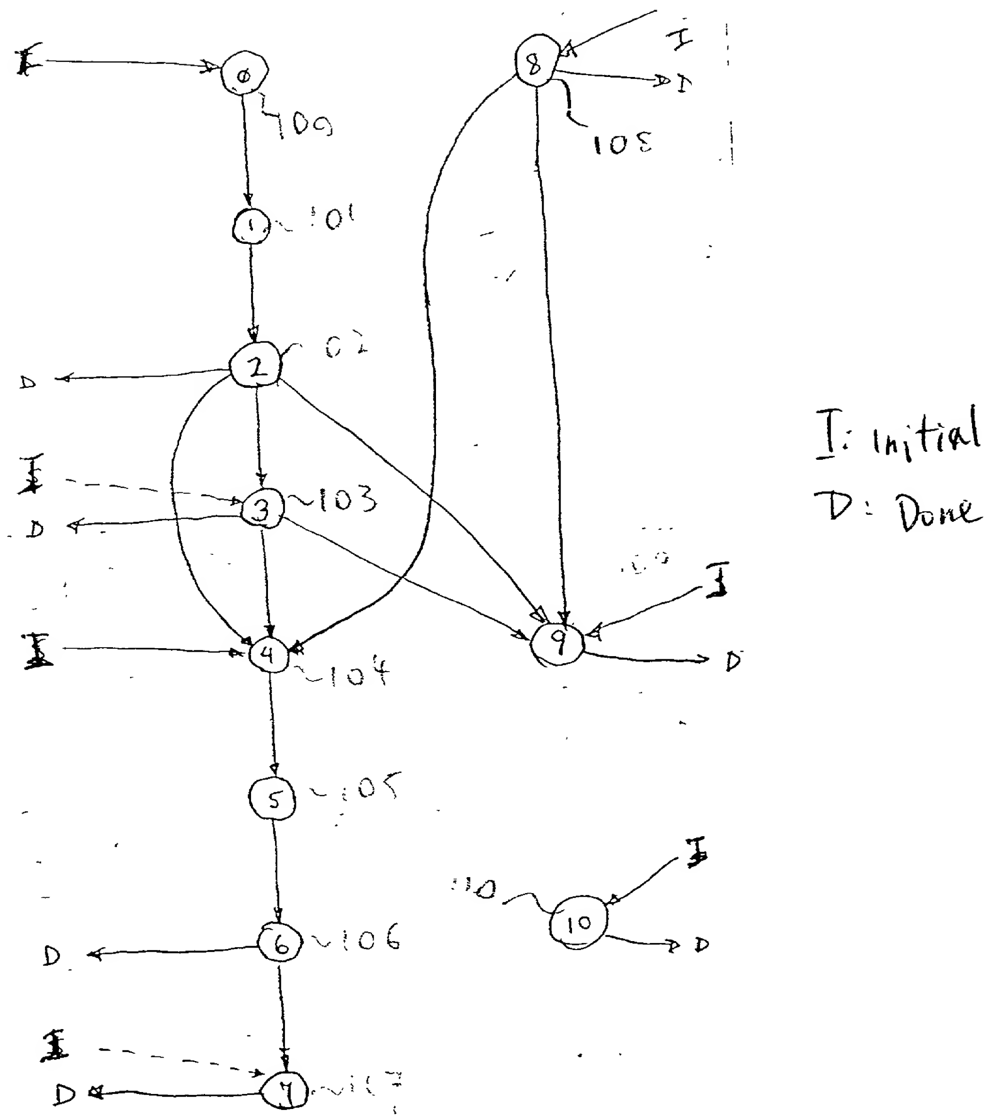


Fig 4b

120 ~	Texture State Operation 0	$S_t = S_i$
121 ~	Texture State Operation 1	$T_t = T_i$
122 ~	Texture State Operation 2	$S_t = S_i * W_o$
123 ~	Texture State Operation 3	$T_t = T_i * W_o$
124 ~	Texture State Operation 4	$S_t = S_i * Range$
125 ~	Texture State Operation 5	$T_t = T_i * Range$
126 ~	Texture State Operation 6	$S_t = S_i * Size$
127 ~	Texture State Operation 7	$T_t = T_i * Size$

Figure 5a

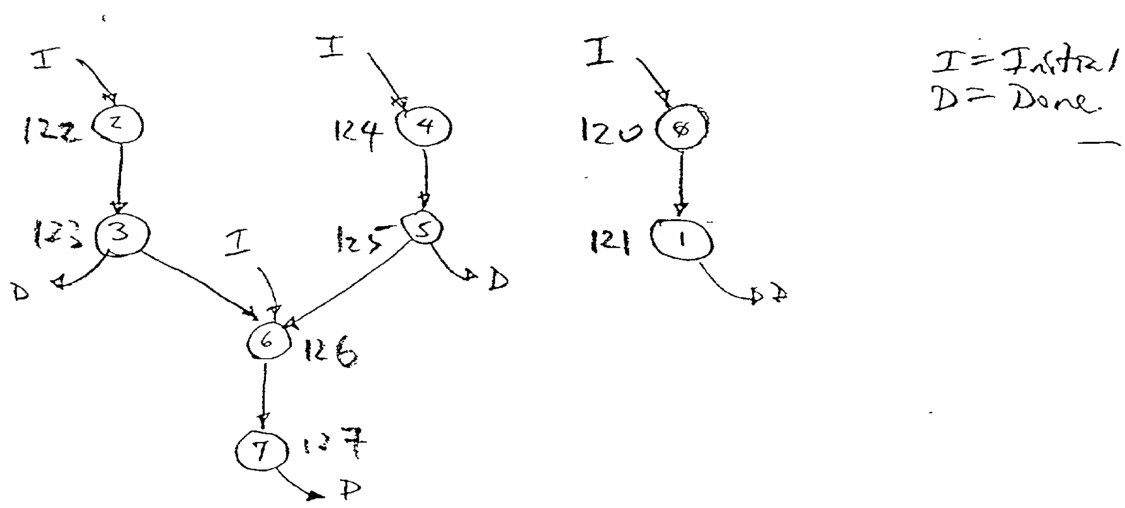
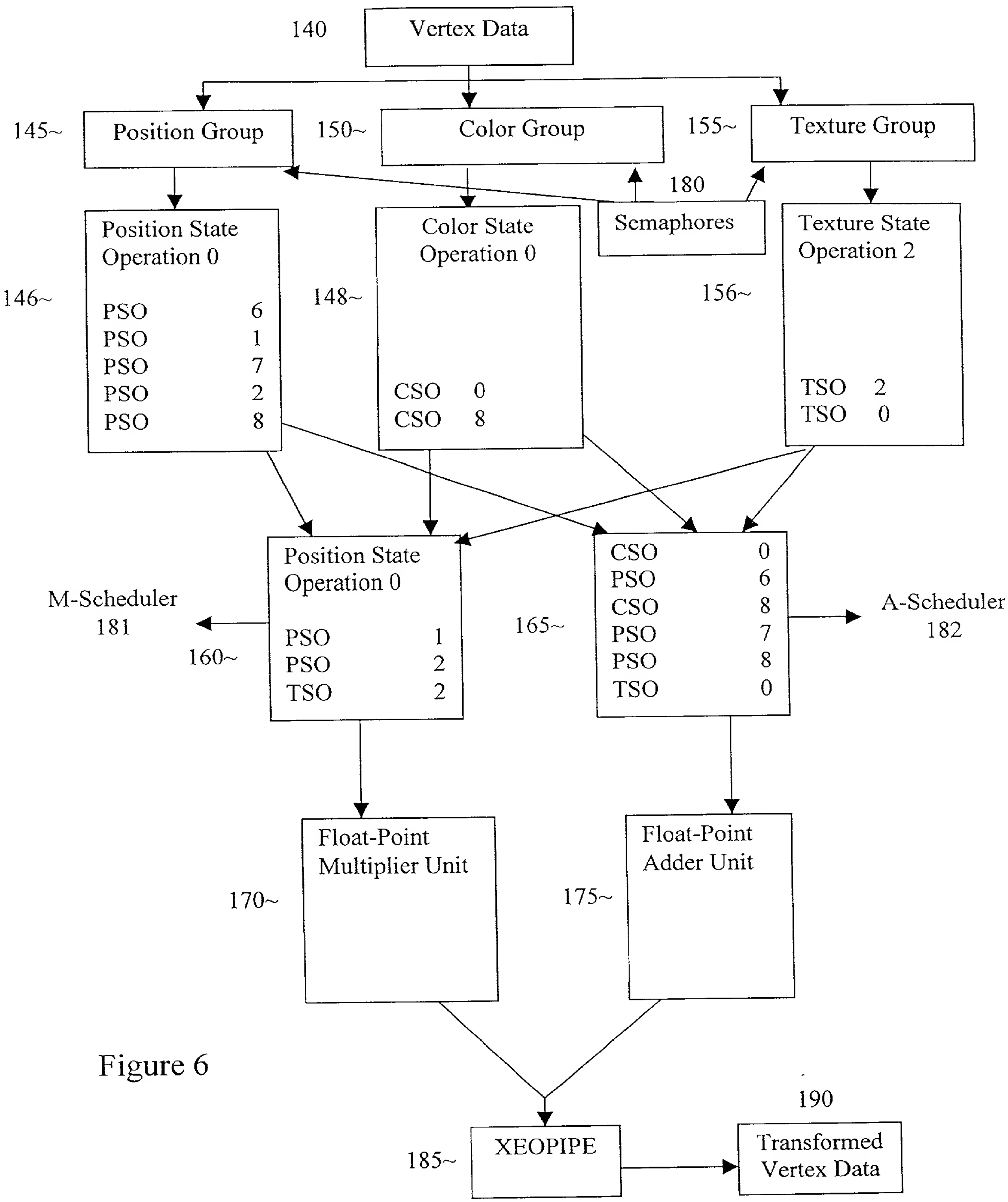


Figure 5b



140
Vertex Data
145~
Position Group
150~
Color Group
155~
Texture Group
180
Semaphores
Position State Operation 0
146~
PSO 6
PSO 1
PSO 7
PSO 2
PSO 8
Color State Operation 0
148~
CSO 0
CSO 8
Texture State Operation 2
156~
TSO 2
TSO 0
M-Scheduler 181
Position State Operation 0
160~
PSO 1
PSO 2
TSO 2
165~
CSO 0
PSO 6
CSO 8
PSO 7
PSO 8
TSO 0
A-Scheduler 182
Float-Point Multiplier Unit
170~
Float-Point Adder Unit
175~
185~
XEOPIPE
190
Transformed Vertex Data

Figure 6

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DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)

☒ Declaration Submitted with Initial Filing OR ☐ Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)

Attorney Docket Number	ATI-000118BN
First Named Inventor	Selvaggi et al.
COMPLETE IF KNOWN	
Application Number	Not Yet Known
Filing Date	Not Yet Known
Group Art Unit	Not Yet Known
Examiner Name	Not Yet Known

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

VERTEX DATA PROCESSING WITH MULTIPLE THREADS OF EXECUTION

(Title of the Invention)

the specification of which

☒ is attached hereto

OR

☐ was filed on (MM/DD/YYYY) ______ as United States Application Number or PCT International Application Number ______ and was amended on (MM/DD/YYYY) ______ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached? YES	NO
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐

☐ Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto:

I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below.

Application Number(s)	Filing Date (MM/DD/YYYY)	
		☐ Additional provisional application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

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DECLARATION — Utility or Design Patent Application

I hereby claim the benefit under 35 U.S.C. 120 of any United States application(s), or 365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. Parent Application or PCT Parent Number	Parent Filing Date (MM/DD/YYYY)	Parent Patent Number *(if applicable)*

☐ Additional U.S. or PCT international application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

As a named inventor, I hereby appoint the following registered practitioner(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: ☐ Customer Number [ ] → *Place Customer Number Bar Code Label here*
OR
☒ Registered practitioner(s) name/registration number listed below

Name	Registration Number	Name	Registration Number
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Anthony S. Volpe	28,377	Jeffrey M. Glabicki	42,584
C. Frederick Koenig III	29,662	Kao H. Lu	43,761
Randolph J. Huis	34,626	Sally Daub	41,478
Gerald B. Halt, Jr.	37,633		

☐ Additional registered practitioner(s) named on supplemental Registered Practitioner Information sheet PTO/SB/02C attached hereto.

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Name of Sole or First Inventor: ☐ A petition has been filed for this unsigned inventor

Given Name (first and middle [if any])	Family Name or Surname
Richard J.	Selvaggi

Inventor's Signature	[signature]					Date	8-3-00
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☒ Additional inventors are being named on the 1 supplemental Additional Inventor(s) sheet(s) PTO/SB/02A attached hereto

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ADDITIONAL INVENTOR(S)
Supplemental Sheet
Page 1 of 1

Name of Additional Joint Inventor, if any: [X] A petition has been filed for this unsigned inventor

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Name of Additional Joint Inventor, if any: [ ] A petition has been filed for this unsigned inventor

Given Name (first and middle [if any])						Family Name or Surname		
Inventor's Signature						Date		
Residence: City		State		Country		Citizenship		
Post Office Address								
Post Office Address								
City		State		ZIP		Country		

Name of Additional Joint Inventor, if any: [ ] A petition has been filed for this unsigned inventor

Given Name (first and middle [if any])						Family Name or Surname		
Inventor's Signature						Date		
Residence: City		State		Country		Citizenship		
Post Office Address								
Post Office Address								
City		State		ZIP		Country		